Roughness on Virginia's Roads

2003 Annual Roughness Report

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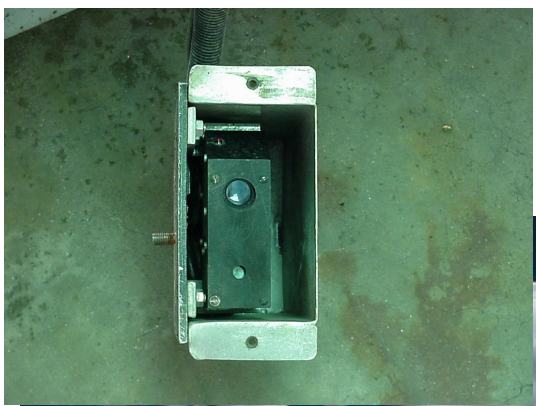

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Executive Summary

To most people, a smooth road is a good road. Although transportation agencies measure many parameters to assess the condition of a highway network, ride quality of the pavement is the main attribute the traveling public measures. This conclusion is also reflected in numerous national studies that have placed ride quality at or near the top of the list of importance to travelers. Accordingly, the Federal Highway Administration set ride quality goals for the national highway system network to reduce road roughness, decrease vehicle use costs, and prolong the life of pavements.

This report utilizes data collected for FHWA to provide an overview of the road conditions throughout Virginia and present trends in ride quality statewide, as well as by district. Included in this annual report are the following:

- Discussion of roughness collection data,
- Summary of the work completed in 2003, and
- Summary of observations based on the findings of the study.

Roughness data is collected through a *road profiler* mounted on the front of a van. The road profiler is a sensor package consisting of one laser and accelerometer mounted in each wheel path and a third sensor located in the center of the bumper. It is equipped with software that converts the longitudinal profile readings to International Roughness Index (IRI). The IRI data is summarized for each district and highway system into one of five qualitative categories as shown below. An IRI of zero represents a perfectly smooth pavement; as IRI increases, so does the roughness.

Qualitative Category	IRI Range (inches/mile)
Excellent	<60
Good	60-100
Fair	100-140
Poor	140-200
Very Poor	>200

Data quality must be accurate and repeatable so that analysis will lead to valid conclusions. A formal verification program was implemented in 2001 to verify the equipment and operators used

for roughness data collection. A one-mile section on Technology Boulevard (located at the Materials Division) was selected as a test site to verify the equipment. In 2003, an additional verification site was established near the Lynchburg NDT unit office. Tests were performed on a weekly and monthly basis with the profiler, and in-house sensor checks were performed every week to ensure all equipment was working properly.

The results of this study indicate an overall improvement since 1998 in overall ride quality for non-interstate highways. For interstates, the ride quality declined from 2002 to 2003 after steadily improving from 1998 to 2002. Much of the decline in interstate ride quality can be attributed to the severe weather and pavement breakup following the 2002-2003 winter season. However, it must be noted that many of the non-interstate routes were surveyed in 2002 prior to the winter break-up. Therefore, the results in this report may be lower than the actual average IRI in 2003.

For the overall average IRI, the non-interstate routes have improved slightly since 1998 (from 107 in/mi to 104 in/mi), while remaining steady since 2001. For the interstate routes, the overall average IRI has fluctuated between a high of 87 in/mi in 1998 and 2003 to a low of 84 in/mi in 2002. Both systems have maintained at average IRI within a range of 3 in/mi over the last 5 years.

Positive trends can be seen in the increase in the distribution of mileage where the ride quality is "excellent" for both interstate and non-interstate highways. This increase in "excellent" mileage can be attributed to more widespread usage of the ride specification program. For interstate paving projects in 2002, the average IRI was 60 in/mi while the non-interstate paving projects have shown steady improvement since 1998. However, the mileage paved under the schedules (with or without the ride spec) has not been enough to offset an increase in "poor" and "very poor" mileage.

This report was based on a high-level analysis of ride quality data collected over the last two years and compared to data collected since 1998. Although the author noted trends and observations, in-depth pavement data analysis was beyond the scope of this report. Areas for further research may include but are not limited to:

- Relationship of vehicle miles traveled to IRI by district,
- Performance of individual routes,
- Analysis of Highway Performance Monitoring System (HPMS) goals to VDOT's paving program,

- Comparison of maintenance expenditures to pavement performance,
- Comparison of maintenance activities to pavement performance, and
- Evaluation of pavement performance targets based on ride quality.
- Comparison of IRI and pavement age.

INTRODUCTION[1]

VDOT's Mission Statement is - "VDOT will plan, deliver, and maintain on-time and on-budget, the best possible transportation system for the traveling public".[2] This statement further emphasizes a goal set in 1998 that VDOT was to become a more customer-driven, customer-focused organization.[3] VDOT's customers want the agency to be good financial stewards of the tax dollars and provide the best highway network to ensure efficient movement of people and goods.

These statements are in line with findings from surveys conducted by the FHWA in 1995 and 2000 that reflect an increase in satisfaction with major highways. From the many attributes of the major highways that travelers were more satisfied in 2000 than 1995, pavement condition was noted. (For the purpose of the survey, pavement condition included surface appearance, durability and quiet ride.) Results from the survey indicated that 21% of responding highway travelers named pavement conditions as the characteristic that should receive the most attention and resources for improvement. This characteristic came third behind traffic flow (28%) and safety (26%) as chosen by the public.[4]

Every year, money and resources are allocated towards the maintenance and repair of the roads throughout the Commonwealth of Virginia. With good information on the roughness condition of the roadways in Virginia, it would be possible to allocate resources in a way that maximizes their performance.

An additional response to increase customer satisfaction took place in 1998, with the implementation of a new special provision for rideability (Ride Specification Program). Widely implemented within the last few years, Ride Spec outlines how pavement smoothness is determined by a profiler and categorized with International Roughness Index (IRI) values. Based on these values, a new pay incentive/disincentive program was implemented and applied to the final surface course of the pavement. Ride Spec provides VDOT a method for controlling the quality of the paving throughout the state where it is used.

PURPOSE

In order to continue increasing the overall satisfaction with our highway system, it is important to consider attributes that affect travelers. Roughness is an important aspect of the condition of our highways, as it affects the quality of the ride. It is important to adequately measure and control the quality of the pavement roughness.

In order for VDOT to allocate its resources in a productive manner and produce the best product for its customers, it is necessary to be aware of the conditions of the roads. Accordingly, the purpose of this report is to provide VDOT management with the most accurate information available through an overview of the road roughness throughout Virginia, noting trends statewide and by district for interstate and non-interstate routes, and presenting observations following data analysis.

History

The data collection effort at VDOT has a long history that can trace its roots back to the late 1980s, when the first windshield rating teams were established. There has been several data collection initiatives in the last six years, each focused on a different aspect of highway management. The Pavement Management Program (PMP), the Highway Performance Monitoring System (HPMS), and the Ride Specification Program (Ride Spec) all utilize roughness as a component within their analyses. However, individual program requirements dictate the scope of the collection effort. Because of the differences in the requirements of these studies the data sets vary in the total mileage and what portions of the network were collected.

In 1995, the Maintenance Division of VDOT entered into a four-year contract with PaveTech, Inc. to collect pavement condition data such as distress, rutting, faulting and roughness. Using data collected in 1997, a study was conducted by Mr. Naveed Sami (previously with the Pavement Management Program) to analyze the roughness condition of the state highway network – interstate, primary and selected secondary routes.[5] This study was conducted as part of VDOT's strategic plan, in which the department committed itself to becoming the most effective customer-oriented public agency in Virginia by the year 2000. A similar study was also carried out based on data collected in 1998.[6] Although the 1997 report focused only on roughness, the 1998 report included pavement condition data. These reports outlined the results of the data collection, provided information useful for the allocation of maintenance funds, and established a pavement performance database that could prove very useful in managing the quality of Virginia's roadway system.

After 1998, network level data collection was to be completed as part of the Inventory and Condition Assessment Survey (ICAS); however, various issues with the contractor prevented the data collection. As a result network level pavement data collection testing was not performed during 1999 and 2000.

Materials' Non-Destructive Testing unit (NDT), which is a part of the Pavement Design and Evaluation (PD&E) Section performs special request testing for VDOT. Besides special requests, the NDT section is responsible for collecting roughness data on maintenance and construction projects where the special provision for rideability (Ride Spec) is applied. This unit was used to supply the Federal Highway Administration (FHWA) with data for its Highway Performance Monitoring System (HPMS) program.

The HPMS program is a long-term study that is using roughness to track highway deterioration and develop life cycle measurements. Every year, under this program each state must submit roughness data. As per HPMS guidelines, ride quality data must be updated on two-year cycles. The HPMS program has its own road inventory, which consists of interstate, primary, and secondary roads. This inventory is a sub-set of the entire network and as per the reporting requirements; the roughness is only collected in the primary direction of travel as defined by FHWA. Thus the lane miles collected for HPMS is less than the amount that had been collected by Maintenance during the PaveTech contract. Since network level data had not been collected since 1998, the Pavement Design and Evaluation (PD&E) Section of the Materials Division was requested by the Information Technologies Application Division (formerly Data Management Division) to collect this information. Using VDOT personnel and equipment, supplemented with vendor resources secured through a Maintenance Division contract, IRI data was collected and processed to comply with a HPMS submission deadline of June 2001.

For the June 2003 HPMS submission to FHWA, the PD&E Section initiated data collection in January 2002. While ride quality data must be refreshed on a two-year cycle to meet HPMS requirements, the PD&E section decided to collect interstate roughness on an annual basis to ensure the most current data possible was supplied to FHWA. Additionally, data collection focused on both primary (north and east) and secondary (south and west) directions to provide a complete picture of roughness. For the non-interstate system, data will be collected on a bi-annual basis. Network level data collection was completed in March 2003.

ROUGHNESS DATA COLLECTION

Roughness Data

Roughness is defined as the deviations of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage (ASTM E867).[7] Longitudinal surface profile data are collected through sensors mounted on the front of a van as shown in Figure 1. The sensor package, known as a *road profiler*, consists of one laser and accelerometer mounted in each wheel path, and a third sensor located in the center of the bumper. The sensors located over the wheel paths are used for roughness measurements. The sensor mounted in the middle of the bumper is used for rut-depth calculations.

Figure 1 – Road Profiler

The International Roughness Index (IRI) is used to categorize the quality of the roadways profiled using the equipment described above. The IRI is an index resulting from a mathematical simulation of vehicular response to the longitudinal profile of a traveled surface using the quarter car simulation model and a traveling speed of 50 miles per hour.[8] Typically, average IRI values for individual wheel paths are reported for every 0.1-mile section for network level analysis. The road profiler is equipped with a data acquisition system and software that converts the longitudinal profile readings to International Roughness Index (IRI) values, which have units of inches per mile. Lower IRI means less deviation in the pavement's surface; an IRI of zero represents a perfectly smooth pavement.

A standardized method of categorizing the IRI into qualitative descriptions has been developed over the years and was used to determine the roughness categories used in this report. This

method is based on the following nationally recognized equation that correlates the IRI and the Present Serviceability Index (PSI): [9]

$$PSI=5 \times e^{-0.0041 \times IRI}$$

The PSI is used to represent the serviceability of a pavement. Since the functional performance of a pavement concerns how well the pavement serves the user, ride quality/ride comfort is considered the dominant characteristic. To quantify riding comfort, the "serviceability-performance" concept was developed by the AASHO Road Test staff in 1957. Comfort or riding quality is a matter of user opinion and can be expressed by the mean of the ratings given by all highway users. This method yields a serviceability rating. Some physical characteristics of a pavement can be measured objectively and then related to subjective evaluations. This procedure produces an objective serviceability index. The PSI is obtained from measurements of roughness and distress such as cracking, patching and rut depth, at a particular time during the service life. The scale for PSI ranges from 0 through 5, with a value of 5 representing the highest index of serviceability. [10]

In order to provide the most accurate comparison over time, this report employs the same categories utilized within Mr. Sami's 1997 report. Table 1 contains a summary of these roughness categories..

Qualitative Category	IRI Range (inches/mile)
Excellent	<60
Good	60-100
Fair	100-140
Poor	140-200
Very Poor	>200

Table 1 – Roughness Categories

Limitations

For any pavement evaluation project, there are limitations in the data collection and data analysis. The following sections outline the predominate limitations.

Data Collection

A number of factors that have an effect on the validity of the data collected with the road profiler must be taken into consideration during the measurement process. For example, bridge decks and approach slabs typically produce significantly different roughness values than the adjacent paved sections. Urban areas also present a challenge for the data collection process. The equipment used to collect the data must be operated at a minimum speed of approximately 30 mph to obtain reliable data, which can prove difficult with numerous stoplights and heavier traffic conditions. Additionally, intersections and manholes produce significantly different roughness values than

their surroundings, which can affect the overall roughness of the section of roadway. This results in some routes not having reportable ride quality data. Road geometry can also present some challenges for the data collection process when there are numerous sharp curves, intersections and steep grades within the section that may adversely affect IRI values. Finally, construction projects will restrict collection efforts.

It is important that these areas are noted during the data collection process to enable the user to remove sections of questionable data from the analysis. This process is consistent with the HPMS data collection guidelines and department protocols as well.

Data Analysis

An important consideration when comparing data from year to year is that the number of miles tested varied from year to year. This is because this report utilizes data from several different sources namely PMP and HPMS. It is therefore not possible to compare results based on lane miles. For this study, percentage of total miles tested was used. Because of the size of the network tested, a comparison based on percentages provides a good method for analysis.

Quality Management

Prior to 2001, an informal program was performed by VDOT consisting of in-house sensor checks and field-testing of selected sites. In 2001, a formal verification program was implemented and an additional field test site was established at Elko (Materials Division office). This verification program was not only necessary for VDOT equipment, but also for the vendor that assisted VDOT with the 2001 HPMS data collection. Although the formal program was established to ensure the quality of the data collected for the HPMS submission, it serves to ensure the quality of all further data collection. In 2003, an additional verification site was established near the Lynchburg NDT unit office.

Prior to network level data collection, operators and equipment had to be approved on a one-mile section of roadway located at the Materials Division. This section of road was marked to ensure accurate start and end locations. The ride quality on this section of road varied from approximately 50 in/mi to 110 in/mi. For the verification, a run consisted of five passes along this section. Once the data was collected and processed, the results for each 0.01-mile interval were analyzed. In order for a profiler (operator and equipment) to pass, several criteria on the repeatability of the results had to be met. The repeatability criteria were established using multiple passes of VDOT's and Virginia Transportation Research Council's (VTRC) profilers. The percent difference approach was selected using highest and lowest IRI value from all five runs. Since the section was 1 mile in length, one hundred 0.01-mile sections and ten 0.1-mile sections were analyzed. Table 2 shows the criteria used. As shown in the table, ninety of the one

hundred 0.01-mile sections and ten of the 0.1-mile sections are required to meet the 15 percent difference criteria. Also, seventy-five of the one hundred 0.01-mile sections and ten of the 0.1-mile sections are required to meet the 10 percent difference criteria. Additionally, nine of the 0.1-mile sections are required to meet the 5 percent difference criteria.

Percent Difference (Min IRI / Max IRI)	**Minimum Number of Passing Sections per Length**	
	0.01 mi.	**0.1 mi.**
15%	90	10
10%	75	10
5%	N/A	9

Table 2 – IRI Verification Criteria

The accuracy of each profiler is verified by checking the average of the 5 runs of the control site against the ground-truth values established by numerous runs of VDOT's three profilers. The average of 5 runs of the control site had to be within 5% of the ground-truth value for each 0.1-mile section and within 2% of the ground-truth value for the total section to meet the accuracy requirements.

If the profiler did not meet these criteria, then retesting of the site was performed. If after a second retesting acceptable results were not achieved, then maintenance on the equipment was required.

Once the profiler passed the repeatability check, testing was initiated. For the HPMS data collection, a verification run was performed before any testing was conducted, every 30-calendar days after commencement of testing, and at the completion of the project. Even when HPMS testing is not underway, monthly runs at a verification site are required for VDOT equipment.

WORK SUMMARY FOR 2002 - 2003

For the data collection period ending June 2003, approximately 2,200 directional miles of Interstate routes were collected by the Materials Division for VDOT's HPMS submission to the Federal Highway Administration for performance monitoring and annual reporting. Additionally, approximately 6,600 directional miles of non-interstate data was collected during the 2002-2003 HPMS data collection cycle. All of this non-interstate data was shown as year 2003 since this was the end of the current cycle; however, a majority of the data for the non-interstate routes were collected in 2002 based on the data collection schedule.

Table 3 provides a breakdown of directional miles tested by highway system and maintenance district.

Directional Miles of Highways Tested in 2003 (by District)										
System	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Interstate	251	236	-	522	304	94	138	470	175	2189
Non-Interstate	818	872	918	848	515	666	712	802	407	6558
All Highways	1069	1108	918	1370	819	760	850	1272	582	8747

Note: 1=Bristol, 2=Salem, 3=Lynchburg, 4=Richmond, 5=Hampton Roads, 6=Fredericksburg, 7=Culpeper, 8=Staunton, 9=Northern Virginia

Table 3 – Directional Miles Tested (2003)

Figure 2 shows the distribution of roughness within individual districts for the Interstate system. Similar to previous years, Bristol, Staunton, and Culpeper districts had the highest percentage of interstates in "excellent" and "good" conditions, with the Salem District a close fourth. The Richmond and Northern Virginia districts had the lowest percentage of interstates in the "excellent" category, while the Hampton Roads district had the greatest percentage of interstates in the "poor" and "very poor" category. Bristol, Salem, Fredericksburg, Culpeper, and Staunton districts all had negligible (less than 1.0 mile) "very poor" mileage.

Figure 3 shows the distribution of roughness within individual districts for the Non-Interstate system. The data indicate that Culpeper district had the largest percentage of non-interstates in "excellent" condition, while Bristol, Staunton and Northern Virginia districts had the largest percentage of non-interstates in "poor" and "very poor" conditions.

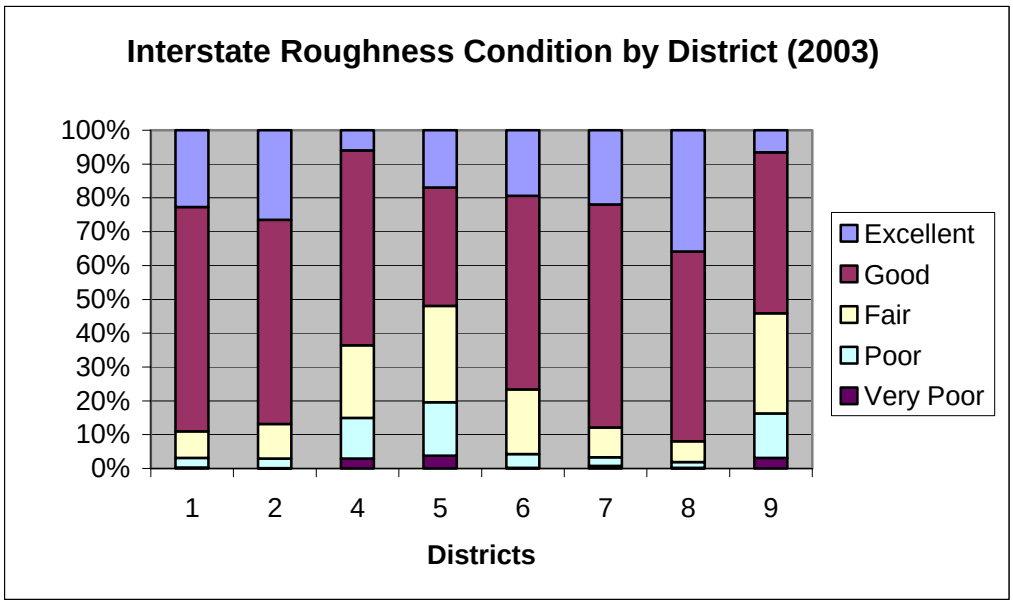

Figure 2 – Interstate Roughness Distribution (2003)

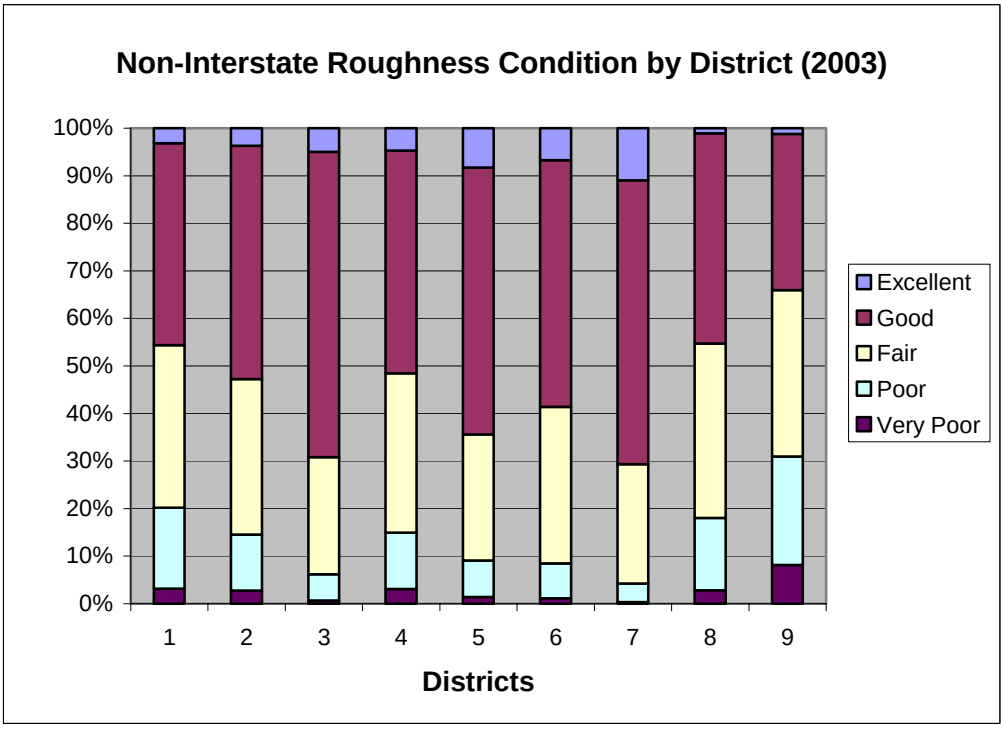

Figure 3 – Non-Interstate Roughness Distribution (2003)

RE-EVALUATION OF THE 2001 ROUGHNESS DATA

After evaluation of the 2002-2003 roughness data, the results were compared to the 2001 data for trend analysis. The largest change in pavement roughness occurred in the non-interstate routes located in the Hampton Roads District. The ride quality improved by more than 10% over a two-year period. With the harsh 2003 winter and the limited number of miles repaved each year, further analysis was conducted to determine the reason for this improvement. In the end, it was determined that several miles of non-VDOT maintained routes, collected for the HPMS data submission, were included in the 2001 averages. These routes were maintained by the localities in the Hampton Roads District and had higher roughness values when compared to the VDOT maintained roads. Table 4 provides a breakdown of directional miles tested by highway system and maintenance district once the non-VDOT mileages were removed.

Directional Miles of Highways Tested in 2001 (by District)										
System	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Interstate	112	118	-	225	134	47	69	234	88	1027
Non-Interstate	737	554	739	758	382	625	588	558	315	5257
All Highways	849	672	739	983	516	672	657	792	403	6284

Note: 1=Bristol, 2=Salem, 3=Lynchburg, 4=Richmond, 5=Hampton Roads, 6=Fredericksburg, 7=Culpeper, 8=Staunton, 9=Northern Virginia

Table 4 – Directional Miles Tested (2001)

As with the 2003 data, results are presented by system and district in Figures 4 and 5. Figure 4 shows the distribution of roughness within individual districts for the Interstate system. The data indicate that Bristol, Salem and Staunton districts had the largest percentage of interstates in "excellent" and "good" conditions. The data also indicate that Hampton Roads district had their interstates more evenly distributed within the "excellent", "good" and "fair" categories.

Figure 5 shows the distribution of roughness within individual districts for the Non-Interstate system. The data indicate that Culpeper district had the largest percentage of non-interstates in "excellent" condition, while Bristol, Staunton and Northern Virginia districts had the largest percentage of non-interstates in "poor" and "very poor" conditions.

Overall, once the non-VDOT routes were removed from the averages, the statewide and Hampton Roads District Non-Interstate IRI results improved. This adjustment had the effect of lowering the statewide average IRI for from 108 to 104. The Hampton Roads District average IRI dropped from 121 to 103 after eliminating the city routes.

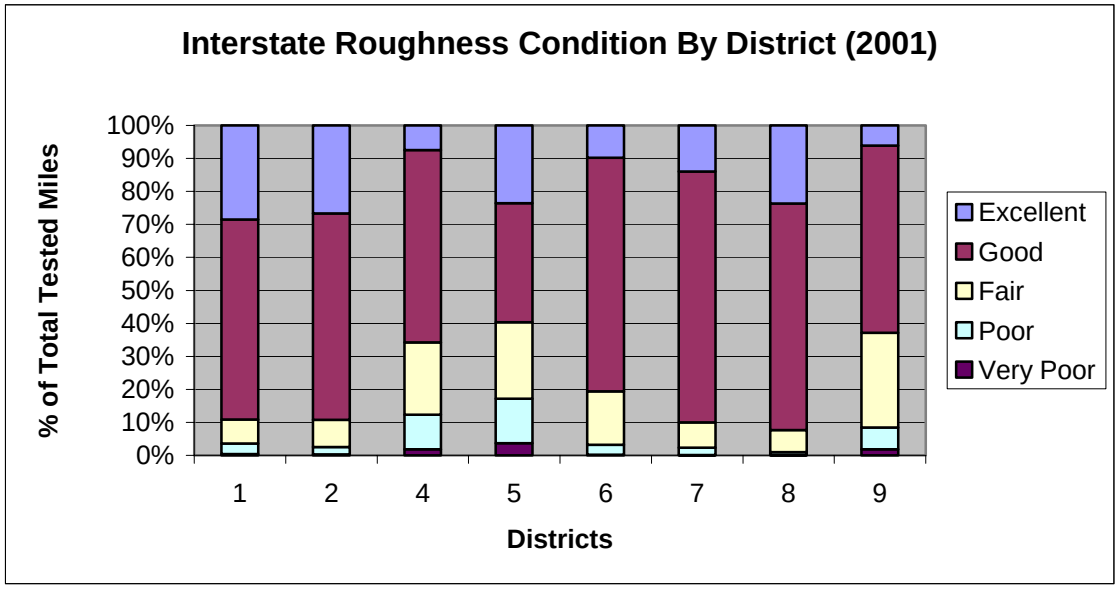

Figure 4 – Interstate Roughness Distribution (2001)

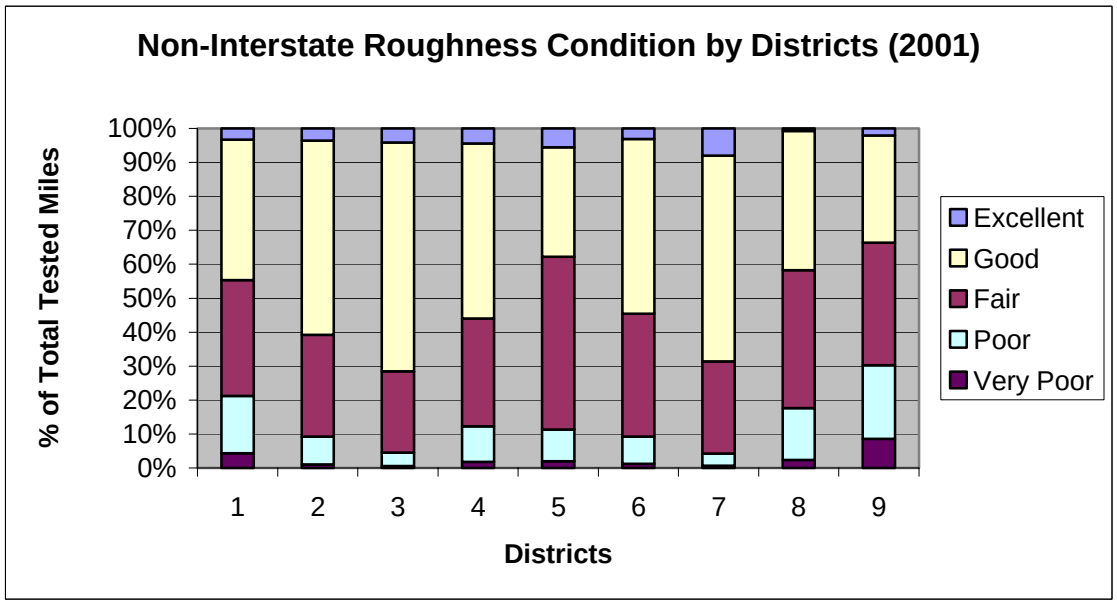

Figure 5 – Revised Non-Interstate Roughness Distribution (2001)

RESULTS AND TRENDS

Over the last five years, results and trends have been noted for the Interstate and Non-Interstate systems. Each system has not deteriorated in overall average ride quality since 1998; however, the winter of 2002-2003 reversed the trend of improving ride quality on the interstates.

Interstates

In order to establish trends in ride quality, data must be examined over a multiple year period. The following graph (Figure 6) shows the statewide Interstate IRI distribution for each year by category of Excellent, Good, Fair, Poor and Very Poor. The data indicate a steady increase in the "excellent" category from 1997 to 2002, with a leveling off in 2003. However, from 2002 to 2003, the "good" category was lowered and the "poor" and "very poor" categories increased.

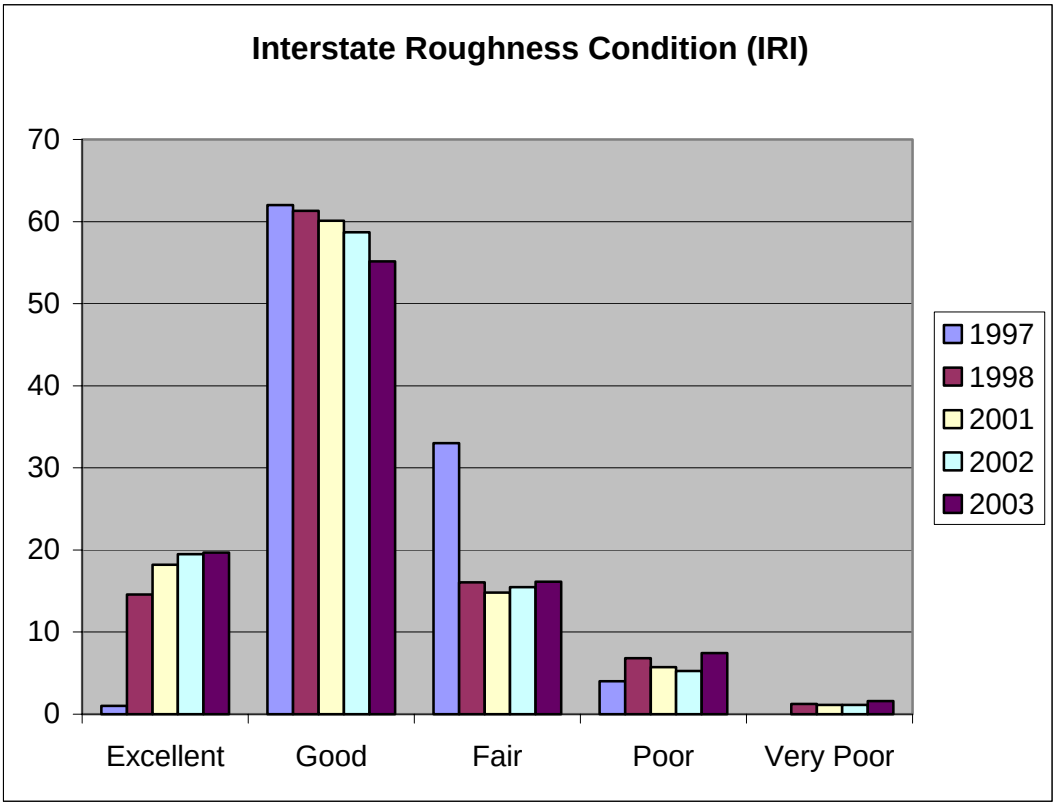

Figure 6 – Statewide Interstate IRI by Year

While Figure 6 displays the trends statewide, Table 5 summarizes the percent change in the Interstate IRI for each district from 1998 to 2003. This table offers each district a view of their progress within the five-year span. While 1997 data were available, the quality of the results

were lower than 1998's. Therefore, to provide a more accurate reference for change in pavement roughness over time, the 1998 results were selected as a baseline.

Category	District								
	1	2	4	5	6	7	8	9	Avg
Excellent	0.54%	1.62%	-5.54%	5.19%	14.27%	12.46%	18.82%	-1.02%	5.10%
Good	0.13%	-3.50%	1.12%	-7.61%	-17.25%	-11.37%	-14.26%	-10.44%	-6.15%
Fair	-0.90%	1.66%	-0.50%	4.91%	1.98%	-0.05%	-3.72%	4.92%	0.07%
Poor	0.24%	0.30%	3.72%	-2.15%	0.94%	-1.41%	-0.85%	4.86%	0.63%
Very Poor	0.00%	-0.09%	1.20%	-0.35%	0.05%	0.36%	0.02%	1.68%	0.34%

Table 5 – Change in Interstate IRI from 1998 to 2003

To interpret Table 5, the following generalities are provided:

- If the "Excellent" or "Excellent" and "Good" categories are positive and remaining categories are negative, then the overall condition of the roads has improved.
- If the "Excellent" and "Good" categories are negative and the "Fair", "Poor" and "Very Poor" categories are positive, then the overall condition of the roads has declined.
- For all other cases, the change in percentages must be evaluated.

Following these generalities, Figure 7 reflects the average IRI by district for the Interstates from 1998 to 2003. The actual average IRI value for 1998 and 2003 are displayed on the graph.

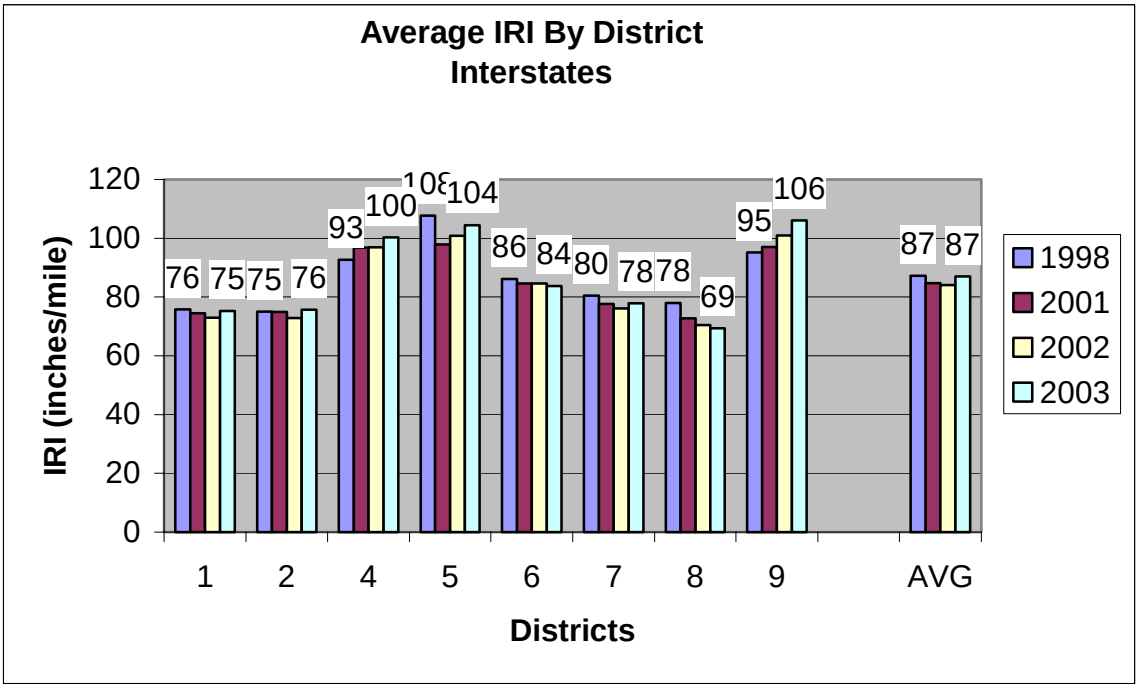

Figure 7 – Interstate Average IRI by District and Year

Except for Salem, Richmond, and Northern Virginia districts, the remaining five districts are showing an improvement in the average IRI for their interstates from 1998 to 2003. However, only Fredericksburg and Staunton districts saw an improvement in average IRI from 2002 to 2003. This may be a function of the wide spread use of the ride spec in the Staunton District and Fredericksburg District. Conversely, six of eight districts are showing an increase in average IRI from 2002 to 2003. The average increase in IRI statewide for the interstate system from 2002 to 2003 was 3 inches per mile.

Appendix A contains the percentages used to develop Figures 6 and 7 and Table 5

Discussion of 2003 Interstate Data

The 2003 interstate data was collected in March and April 2003 after a severe winter and numerous freeze-thaw cycles. This data was all collected after the "pothole blitz" was declared by Governor Warner on March 5, 2003[11] and clearly shows the effects of this winter breakup on the 2003 IRI results for the Interstates.

Non-Interstates

Like the Interstates, the Non-Interstates were evaluated in the same manner. Figure 8 reflects the statewide Non-Interstate IRI for each year by category of "Excellent", "Good", "Fair", "Poor" and "Very Poor". The data indicate an increase in the "Excellent" and "Good" categories and a decrease in the "Fair", "Poor", and "Very Poor" categories from 1998 to 2003. However, from 2001 to 2003, only the "Excellent" category is showing a positive trend, while the "Good" and "Fair" categories are decreasing. In addition, the "Poor" and "Very Poor" categories are increasing. The uptrend in "Excellent" mileage can be largely attributed to more widespread usage of the ride spec from 2001 to 2003. However, the mileage paved under the ride spec was not enough to improve the other categories of condition to offset the continual deterioration of the network.

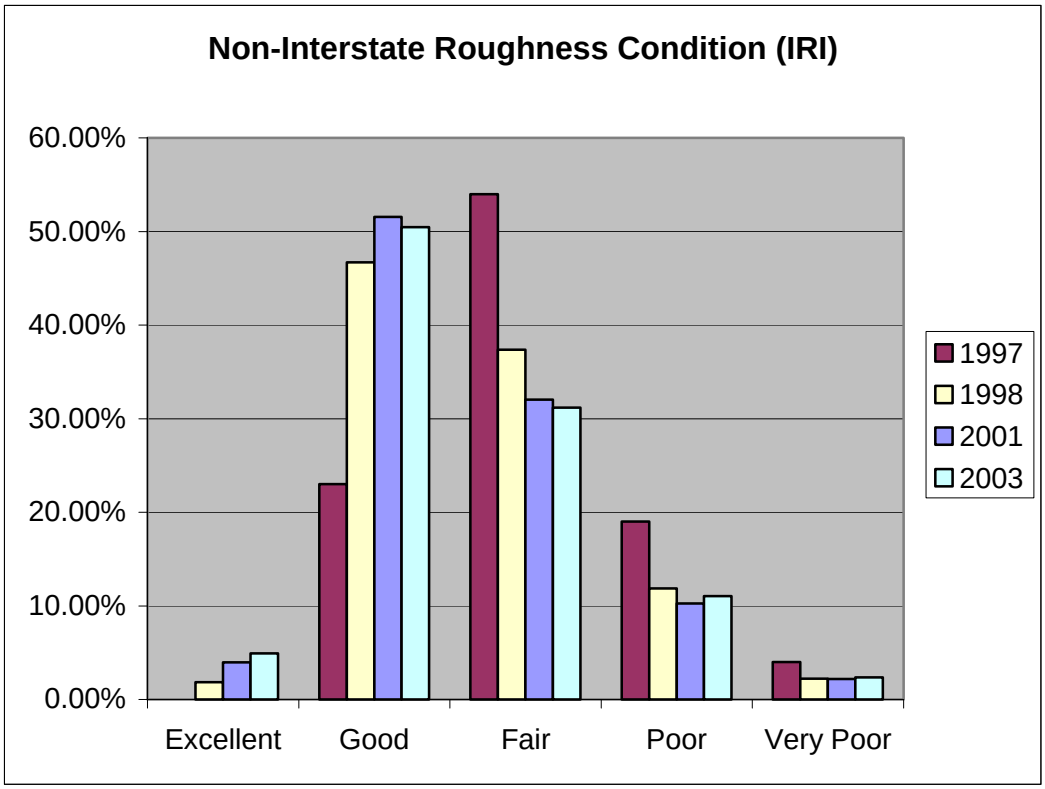

Figure 8 – Statewide Non-Interstate Roughness Distribution by Year

Table 6 summarizes the percent change from 1998 to 2003 in the non-Interstate IRI for each district. This table offers each district a view of their progress within the five-year span. Again, 1998 was selected as the baseline year for trend comparisons due to the superiority of the data collected.

	District									
Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Avg**
Excellent	1.49%	1.87%	2.91%	2.70%	5.76%	4.81%	8.09%	0.21%	0.54%	3.07%
Good	10.35%	2.24%	6.73%	-4.33%	6.03%	0.94%	3.06%	2.33%	5.92%	3.78%
Fair	-8.67%	-5.30%	-7.97%	-1.00%	-7.20%	-5.24%	-7.45%	-3.34%	-12.36%	-6.17%
Poor	-2.06%	0.24%	-1.59%	1.48%	-3.35%	-0.53%	-3.50%	0.28%	3.67%	-0.82%
Very Poor	-1.11%	0.94%	-0.07%	1.15%	-1.24%	0.03%	-0.19%	0.52%	2.23%	0.14%

Table 6 – Change in Non-Interstate IRI from 1998 - 2003

Based on Table 6, Bristol, Lynchburg, Hampton Roads and Culpeper have seen positive trends by shifting a higher percentage of their roads into the "excellent" and "good" categories, while

reducing their "fair", "poor", and "very poor" categories. However, Salem, Richmond, Staunton, and Northern Virginia districts have all seen increases in the "poor" and "very poor" categories. Overall, this has resulted in lower IRI values as compared to 1998 and very similar IRI values compared to 2001.

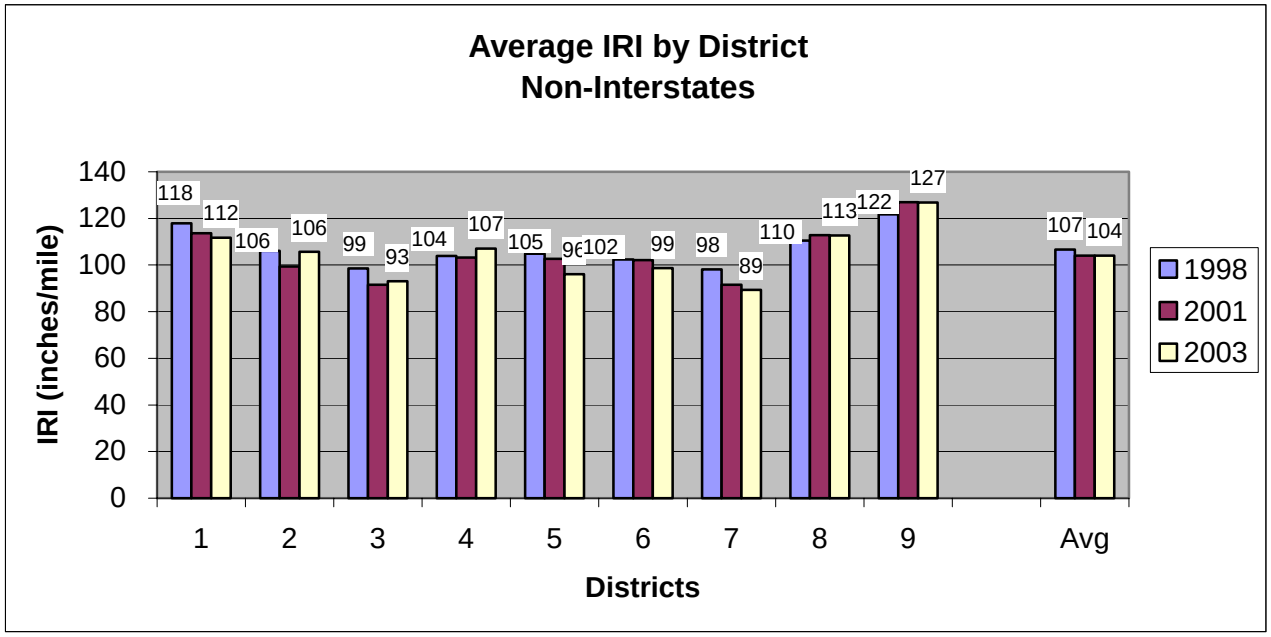

Figure 9 – Non-Interstate Average IRI by District and Year

Figure 9 displays the average IRI by District for non-Interstates from 1998 to 2003. The data indicates that all districts except Richmond, Staunton and Northern Virginia were showing an improvement in the average IRI for their Non-Interstates from 1998 to 2003. From 2001 to 2003, Bristol, Hampton Roads, Fredericksburg, and Culpeper were showing an improvement in average IRI, while Salem, Lynchburg, and Richmond were showing an increase in average IRI. The overall average IRI has decreased from 1998 to 2003 but was unchanged from 2001 to 2003.

Appendix B contains the percentages used to develop Figures 8 and 9 and Table 6.

Pavement Surface Type (Interstates Only)

Two surface types exist on the interstate system in Virginia – asphalt concrete (AC) and Portland Cement Concrete (PCC). Only three districts have interstate mileage where more than 8 centerline miles of each type were present: Richmond, Northern Virginia and Hampton Roads. Except for sections of I-64 in Hampton Roads and a section of I-66 in Northern Virginia, most of the existing PCC surfaces have been in service for more than 15 years. Many of these surfaces

have experienced varying levels of distress, which has resulted in less than desired ride quality. For the AC surfaces in these same districts, the majority has been in place less than 10 years. Recognizing the difference in condition and ages, an analysis was performed to determine the effect of surface type on these districts IRI averages and distributions from 1998 to 2003.

As in 2002, all of the interstate network was collected in both directions. Figure 10 shows the distribution by pavement type and district. Table 7 provides the mileage collected and average IRI by pavement type.

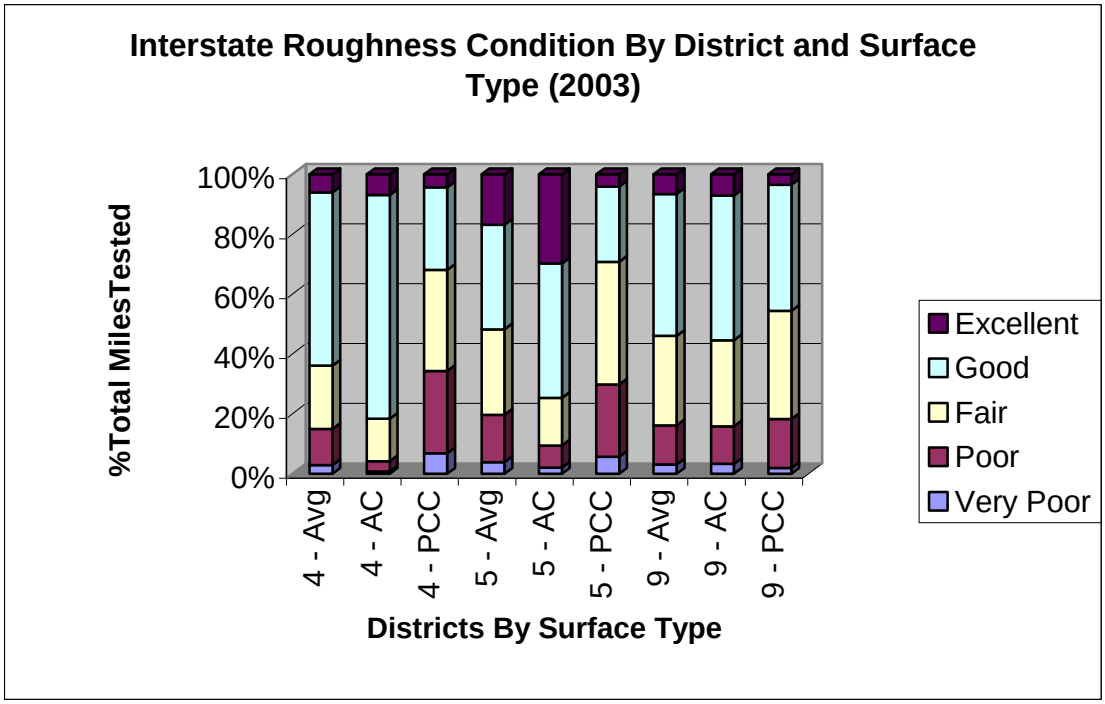

Figure 10 – Interstate IRI by District and Surface Type (2003)

District	Mileage			IRI		
	PCC	AC	Total	PCC	AC	Average
Richmond	186	334	520	126	86	100
Hampton Roads	154	152	306	124	85	104
Northern Virginia	26	151	177	111	105	106

Table 7 – Mileages and Average IRI by Pavement Type (2003)

Effect of Surface Type on Average Interstate IRI

For each of the three districts in Virginia that have a substantial amount of PCC and AC surfaces on the interstate system, the average ride quality is a function of the surface. In the Hampton Roads and Richmond Districts, the ride quality is much worse on the PCC surfaces compared to the AC surfaces. In 2003, the average IRI on PCC surfaces was over 30 inches per mile higher than the AC surfaces. Additionally, these three Districts were the only three Districts that had an average IRI of 100 or greater for the interstates.

As with the Interstate and Non-Interstate systems, Table 8 summarizes the percent change from 1998 to 2003 in the Interstate IRI for each district based on surface type. This table offers each district a view of their progress within the four-year span. Again, 1998 was selected as the baseline year for trend comparisons due to its data quality.

Category	Percent Change By District from 1998 - 2003								
	4 - Avg	**4 - AC**	**4 - PCC**	**5 - Avg**	**5 - AC**	**5 - PCC**	**9 - Avg**	**9 - AC**	**9 - PCC**
Excellent	-5.54%	-7.43%	-2.26%	4.94%	8.89%	2.04%	-1.02%	-1.29%	2.50%
Good	1.12%	6.76%	-8.58%	-6.64%	0.70%	-13.45%	-10.44%	-9.18%	-19.72%
Fair	-0.50%	1.41%	-4.60%	4.78%	-4.54%	13.54%	4.92%	4.91%	4.47%
Poor	3.71%	-0.72%	11.96%	-2.58%	-4.23%	-1.77%	4.87%	3.87%	10.85%
Very Poor	1.20%	-0.02%	3.48%	-0.49%	-0.82%	-0.37%	1.68%	1.69%	1.90%

Table 8 – Change in Interstate IRI by Surface Type from 1998 – 2003

For the PCC surfaced interstate in all three Districts, the average IRI has increased from 1998 to 2003. From 2002 to 2003, the average IRI has increased in Richmond and Northern Virginia while decreasing in Hampton Roads for PCC surfaces. The improvement in the Hampton Roads District may have resulted from extensive patching to repair deteriorated sections of pavement.

The AC surfaced Interstates in these three Districts were showing the same trend. From 1998 to 2003, the average IRI has increased in both Richmond and Northern Virginia, while decreasing in Hampton Roads for AC surfaces. From 2002 to 2003, the average IRI increased for all three Districts with AC surfaces. The average IRI was 124 for PCC surfaces and 90 for AC surfaces in 2003 for the three Districts analyzed.

VDOT'S COMPARISON TO HPMS GOALS

As the Federal Highway Administration determines how much federal funding each state will be allocated every year, it sets goals that each state must work toward. Based on the results of the 1995 National Quality Initiative customer survey, improving ride quality nation-wide was a FHWA goal.[12] Therefore, a goal was set to increase the percent of the NHS mileage (as reflected in HPMS reported data) with an IRI of 170 inches per mile or less from 91.7% in 1998 to 93.0% by the year 2008.[13] Since then, the goal for 2008 was revised and included a secondary target.[14] The revised goal is for 95% of the NHS travel mileage (as measured by Vehicle Miles of Travel (VMT)) to be on pavement no rougher than 170 inches per mile, the FHWA upper limit for acceptable ride quality. The target in the new goal is that at least 60% of the travel occurring on the NHS will be on pavements with a roughness of 95 inches per mile or less, the FHWA upper limit for good ride quality. For the year 2003, the FHWA performance plan established the goal to have 92.5% of all VMT on the NHS to be on highways no rougher than 170 inches per mile. [15]

Using data collected and submitted to FHWA in June 2003, an analysis was performed to see if VDOT met these new goals for acceptable and good ride quality. Based on the analysis of the VMT and average IRI, VDOT exceeded the 2003 goal of 92.5% by 1.5%, with a value of 94%. In other words, only 6% of the VMT on VDOT's NHS roads had an average IRI greater than 170 in/mi. Over the next five years, the percentage will need to increase by 1% to meet the FHWA goal of 95% by 2008. Currently, ninety-five percent of the VMT is on roads with an average IRI of 171 in/mi or less. For good pavement, approximately 56% of the VDOT-maintained NHS mileage has an average IRI of 95 inches per mile or less. Based on the data collected in the 2002-2003 data collection cycle, sixty percent of VMT is on roads with an average IRI of 101 in/mi or less. To meet the 60% goal set as a secondary target, VDOT will have to improve the ride quality on many of the heaviest-traveled routes – interstates and high-volume primaries, over the next five years.

CONCLUSIONS

The overall ride quality on Virginia's highways has not deteriorated since 1998 (see Figure 11) for non-interstates. For interstates, the ride quality declined in 2003 after steadily improving from 1998 to 2002. Much of this decline in the interstate ride quality can be attributed to the severe weather and pavement breakup following the 2002-2003 winter season and corresponded with the time frame of data collection in March and April of 2003. This decline in ride quality throughout the interstate system outweighed the benefits attributed to the widespread use of the ride spec. The benefits of the ride spec are shown in Figure 12, where interstate paving projects averaged an IRI of 60 in 2002 and the non-interstate paving projects have shown steady improvement over the past five years. [16,17]

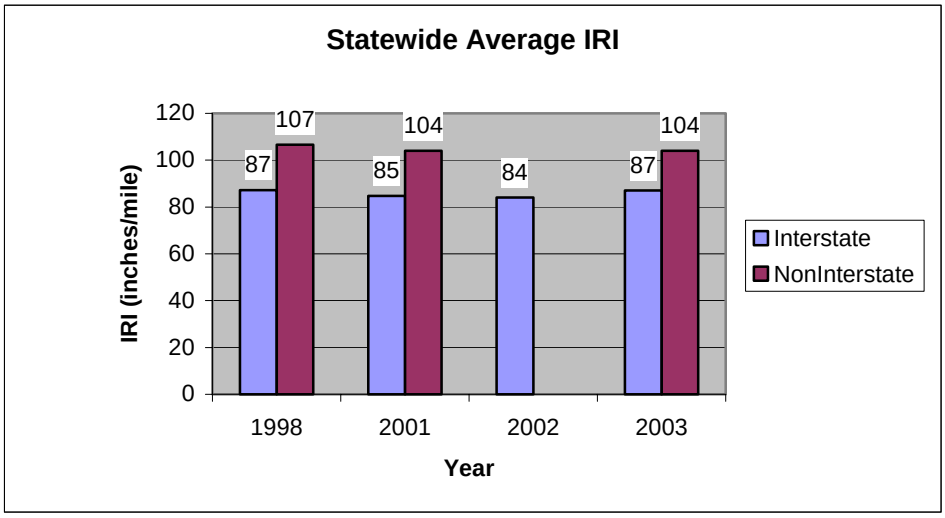

Figure 11 – Statewide Average IRI by System and Year

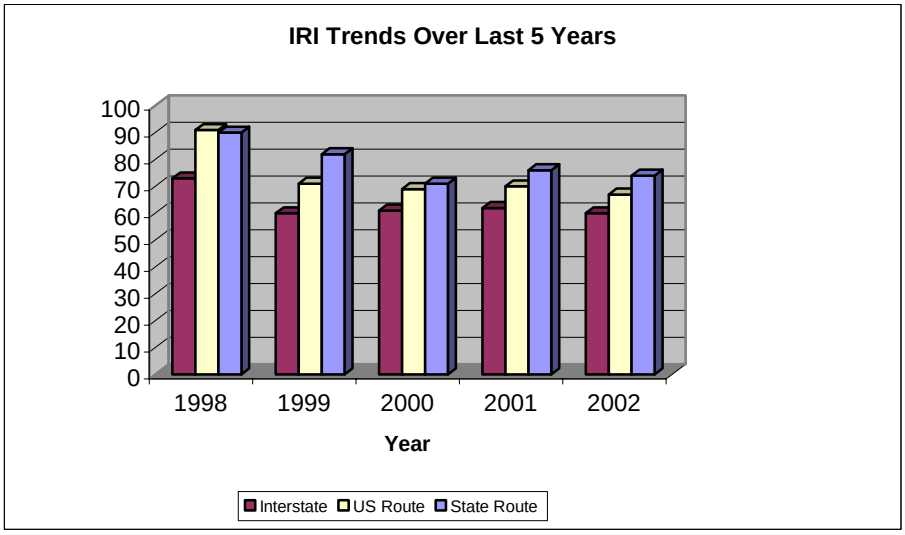

Figure 12 – Maintenance Projects with Ride Spec

This report was based on a high-level analysis of ride quality data collected over the last five years. While the author noted trends and observations, in-depth pavement data analysis was not conducted. Areas for further research may include but not limited to:

- Relationship of vehicle miles traveled to IRI by district,
- Performance of individual routes,
- Comparison of maintenance expenditures to pavement performance,
- Comparison of maintenance activities to pavement performance, and
- Evaluation of pavement performance targets based on ride quality.

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APPENDICES

APPENDIX A – DATA SUMMARY FOR INTERSTATES

Interstate Roughness Condition - Statewide

	1998	2001	2002	2003
Excellent	14.57	18.2	19.47	19.67
Good	61.3	60.12	58.69	55.15
Fair	16.05	14.8	15.46	16.12
Poor	6.82	5.74	5.26	7.45
Very Poor	1.26	1.14	1.12	1.60

Interstate Roughness Condition by District - 1998

	1	2	4	5	6	7	8	9
Excellent	22.17%	24.85%	11.52%	11.77%	5.11%	9.46%	17.04%	7.59%
Good	66.23%	63.83%	56.49%	42.59%	74.54%	77.29%	70.38%	57.98%
Fair	8.72%	8.61%	21.95%	23.58%	17.08%	8.88%	9.85%	24.68%
Poor	2.63%	2.54%	8.34%	17.89%	3.11%	4.01%	2.55%	8.28%
Very Poor	0.24%	0.17%	1.69%	4.17%	0.16%	0.36%	0.17%	1.46%

Interstate Roughness Condition by District - 2001

	1	2	4	5	6	7	8	9
Excellent	28.56%	26.68%	7.47%	23.55%	9.83%	13.98%	23.71%	6.11%
Good	60.59%	62.53%	58.31%	36.07%	70.73%	76.08%	68.61%	56.79%
Fair	7.30%	8.24%	21.91%	23.17%	16.24%	7.64%	6.70%	28.62%
Poor	3.20%	2.29%	10.49%	13.56%	2.99%	2.16%	0.90%	6.67%
Very Poor	0.36%	0.25%	1.82%	3.65%	0.21%	0.14%	0.09%	1.81%

Interstate Roughness Condition by District - 2002

	1	2	4	5	6	7	8	9
Excellent	23.49%	29.32%	6.80%	18.97%	12.47%	19.56%	29.66%	6.42%
Good	68.79%	61.42%	58.53%	36.49%	65.87%	70.71%	63.13%	50.73%
Fair	6.41%	8.05%	23.14%	27.40%	17.75%	8.71%	6.51%	31.74%
Poor	1.30%	0.89%	9.61%	13.70%	3.84%	0.60%	0.60%	9.17%
Very Poor	0.00%	0.32%	1.92%	3.43%	0.08%	0.43%	0.10%	1.93%

Interstate Roughness Condition by District - 2003

	1	2	4	5	6	7	8	9
Excellent	22.71%	26.47%	5.98%	16.96%	19.38%	21.92%	35.86%	6.57%
Good	66.36%	60.33%	57.61%	34.98%	57.29%	65.92%	56.12%	47.54%
Fair	7.82%	10.27%	21.45%	28.49%	19.06%	8.83%	6.13%	29.60%
Poor	2.87%	2.84%	12.06%	15.74%	4.05%	2.60%	1.70%	13.14%
Very Poor	0.24%	0.08%	2.89%	3.82%	0.21%	0.72%	0.19%	3.14%

Percent Change by District from 1998 - 2003

	1	2	4	5	6	7	8	9
Excellent	0.54%	1.62%	-5.54%	5.19%	14.27%	12.46%	18.82%	-1.02%
Good	0.13%	-3.50%	1.12%	-7.61%	-17.25%	-11.37%	-14.26%	-10.44%
Fair	-0.90%	1.66%	-0.50%	4.91%	1.98%	-0.05%	-3.72%	4.92%
Poor	0.24%	0.30%	3.72%	-2.15%	0.94%	-1.41%	-0.85%	4.86%
Very Poor	0.00%	-0.09%	1.20%	-0.35%	0.05%	0.36%	0.02%	1.68%

APPENDIX B – DATA SUMMARY FOR NON-INTERSTATE ROUTES

Non-Interstate Roughness Condition-Statewide

	1998	2001	2003
Excellent	1.85%	3.95%	4.92%
Good	46.69%	51.56%	50.47%
Fair	37.36%	32.05%	31.19%
Poor	11.87%	10.25%	11.05%
Very Poor	2.23%	2.19%	2.37%

Non-Interstate Roughness Condition by District - 1998

	1	2	3	4	5	6	7	8	9
Excellent	1.68%	1.80%	2.08%	1.99%	2.54%	1.90%	2.85%	0.89%	0.69%
Good	32.11%	46.88%	57.43%	51.21%	50.10%	50.97%	56.63%	41.86%	26.91%
Fair	42.84%	37.96%	32.59%	34.50%	33.69%	38.16%	32.56%	40.01%	47.37%
Poor	19.08%	11.55%	7.14%	10.35%	11.03%	7.88%	7.42%	14.93%	19.15%
Very Poor	4.29%	1.82%	0.75%	1.95%	2.64%	1.08%	0.54%	2.31%	5.88%

Non-Interstate Roughness Condition by District - 2001

	1	2	3	4	5	6	7	8	9
Excellent	3.30%	3.61%	4.19%	4.45%	4.53%	3.15%	7.99%	0.74%	2.09%
Good	41.37%	57.17%	67.31%	51.52%	39.92%	51.38%	60.59%	41.01%	31.57%
Fair	34.08%	29.96%	23.95%	31.77%	30.55%	36.22%	27.13%	40.65%	36.07%
Poor	16.93%	8.21%	3.94%	10.47%	16.17%	7.99%	3.59%	15.24%	21.70%
Very Poor	4.32%	1.05%	0.61%	1.79%	8.83%	1.26%	0.70%	2.37%	8.57%

Non-Interstate Roughness Condition by District - 2003

	1	2	3	4	5	6	7	8	9
Excellent	3.17%	3.67%	4.99%	4.69%	8.30%	6.71%	10.94%	1.10%	1.23%
Good	42.46%	49.12%	64.16%	46.88%	56.13%	51.91%	59.69%	44.19%	32.83%
Fair	34.17%	32.66%	24.62%	33.50%	26.49%	32.92%	25.11%	36.67%	35.01%
Poor	17.02%	11.79%	5.55%	11.83%	7.68%	7.35%	3.92%	15.21%	22.82%
Very Poor	3.18%	2.76%	0.68%	3.10%	1.40%	1.11%	0.35%	2.83%	8.11%

Percent Change by District from 1998 - 2003

	1	2	3	4	5	6	7	8	9
Excellent	1.49%	1.87%	2.91%	2.70%	5.76%	4.81%	8.09%	0.21%	0.54%
Good	10.35%	2.24%	6.73%	-4.33%	6.03%	0.94%	3.06%	2.33%	5.92%
Fair	-8.67%	-5.30%	-7.97%	-1.00%	-7.20%	-5.24%	-7.45%	-3.34%	-12.36%
Poor	-2.06%	0.24%	-1.59%	1.48%	-3.35%	-0.53%	-3.50%	0.28%	3.67%
Very Poor	-1.11%	0.94%	-0.07%	1.15%	-1.24%	0.03%	-0.19%	0.52%	2.23%